METZGER

Design of Marine Ways

Civil Engineer

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DESIGN OF MARINE WAYS

BY

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I hereby recommend that the thesis prepared under my personal supervision by LOUIS CHARLES FREDERICK METZGER entitled DESIGN OF MARINE WAYS be accepted as fulfilling this part of the requirements for the degree of CIVIL ENGINEER.

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Head of Department.

Recommendation concurred in:

A N Talbot

Frederick M. Mann

COMMITTEE ON FINAL EXAMINATION.

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INTRODUCTION.

Marine Ways is a place where boats are hauled out of the water to make repairs, or where boats are built.

The writer, having designed and made drawings for a marine ways, desires to put in permanent form the results of his investigation. Search in the accessible engineering literature revealed very little pertaining to marine ways. Descriptions of dry docks and of floating docks were found, but nowhere was mentioned the side-haul marine ways which the author will discuss.

SIDE-HAUL MARINE WAYS.

This term is derived from the fact that boats are hauled out of the water sideways, that is, the keelson lies at right angles to the direction of travel on the ways.

ADVANTAGES.

Though not directly bearing on the design, some of the advantages of side-haul marine ways will be mentioned. They are: (1) the difficulties of the varying stages of the river can be easily met; (2) there is less danger of injuring the hull, for blocking and bracing may be done before the boat is lifted from its floating position; (3) the boat is

brought to the ways with bow upstream and is kept on a horizontal keelson, which makes various operations easier than if in another position; (4) slowly lowering the boat sideways causes less stress in the hull and framing than when launched endwise; and (5) steam may be raised in the boat's boilers so that when the boat again floats due to its own displacement, it can proceed to its regular duties without assistance.

LOCATION.

The location of the marine ways is determined by certain conditions. These are: (1) The ways shall be at the end of the trips of a large number of boats; (2) boat owners will be willing to have boats lay up for repairs at that place; (3) repairs can be made as cheaply as at other places; (4) a boat, while under repairs, is as safe on the ways as elsewhere; and (5) the site shall be easily accessible from the terminal harbor or wharf. Other conditions which are important in the selection of a site are: railway facilities, cost of land and its condition for the purpose, easy access by the workmen, and the natural peculiarities of river and shore.

1.- The above conditions are fully met in a satisfactory manner in St. Louis. All boats stop at St. Louis, and most of them run only south or only north from this harbor. There are no boats now plying the Mississippi River which pass St. Louis.

The Missouri River traffic has St. Louis as its

terminus.

The proposition of the agitators for deep water ways, to make St. Louis the point at which the depth of channel is to change, meets with the approval of the Waterways Commission. When carried out the change in depth of channel will make St. Louis the head of deep water in the Mississippi River.

2.- Repairs to a boat, when necessary, will be made after its cargo has been discharged and at the end of the trip. Boat owners will be willing to have boats lay up for repairs in a harbor where there is a likelihood that business can be obtained during forced idleness of the boat. St. Louis has many factories and warehouses from which some business might be gotten.

3.- There is no valid reason why repairs can not be made as cheaply in St. Louis as any where else, for labor is not dearer and material may be obtained as cheaply as in other towns.

4.- The boat will be safe in St. Louis, for this City has adequate police and fire protection. Nature's forces are not any more likely to damage a boat here than at another place. Safety of the boat depending on the management of the marine ways need not be considered in the location.

5.-It will be assumed that the marine ways will be built at St. Louis, Mo., and that the foregoing conditions are fully satisfied. There are several sites available within a few miles from the center of the improved wharf of St. Louis. Each of these has comparatively deep water right at the foot of a slope, which is very nearly of the right inclination for

a marine ways. These sites are also accessible by rail; and tracks are on or near the wharf almost the full length of the water front so that railway connections can be made at reasonable cost. These tracks are necessary for the delivery to the ways of material as coal, timber, steel, etc., which could not be delivered by boat. In the City of St. Louis better switching service is furnished than can be gotten where less switching is done. Good switching service will reduce storage capacity and length of unloading track otherwise required.

In general the Missouri side of the Mississippi River near St. Louis is steeper than the Illinois side. This reduces first cost of grading for the ways, and tends to offset the higher price and possibly higher tax on the Missouri side of the river.

Both sides are accessible, but the west side has better street car facilities for workmen to reach the ways. More workmen (skilled and unskilled) remain in a place where city conveniences and amusements can be obtained. When needed a larger number of, and better, men can be hired in a large city than in a smaller town.

The water's edge for full length of ways should be straight and close to deep water or to the main channel of the river. No chances should be taken at a place where a sand bar or other obstruction could possibly lodge in front of the ways. Nor should the ways be so situated that a strong current could at any time have a tendency to scour within the limits of the ways.

SLOPE OF THE WAYS.

The slope or grade of the ways depends on the elevation of, and distance at which, the hauling machinery is placed from the river, and also on the restrictions of the U. S. War Department. The fact should not be lost sight of that a flat slope makes it easier to work on the outside of the hull and gives a wider space than a steep slope; but the flatter the slope, the wider the ways must be in order to keep the machinery from being submerged during high water. It is considered impractical to have the floor of the shop more than a few inches above the ground immediately surrounding it; but to keep rain water run-off from flowing into the shop, the floor will be about six inches above ground outside.

According to published reports, the flood stage of the Mississippi River is reached when the river gage reads 30 ft. at St. Louis, Mo. In the last few years the river has been so that the gage read 38 ft. for a short time. From record for several years the average stage of the river has been 13.7 ft.

For safety the machinery will be kept at 40 ft. on river gage.

The War Department, which has control of the navigable rivers, has established wharf lines, and prescribed that on the outer wharf line the ground shall be at or below zero of the river gage and that at the inner wharf line the ground or any obstruction shall be at or below flood height. No permanent obstruction may be placed in the river or between the wharf

lines without special permission from the War Department. An average width of 250 ft. has been established for the wharf; this allows a slope of about one in eight to be used for the ways.

DEFINITION OF WAYLOG & CRADLE.

A waylog is a foundation or prepared way on which is laid and fastened a track over which the boat is hauled. The waylogs run from under the water to the top of the slope. The prepared way was originally made of timbers or logs, and was called waylog, and this name has been retained, though the material used may be very different.

The cradle is defined by Webster as: "A frame work of timbers or iron bars moving upon ways or rollers used to support, lift, or carry ships or other vessels, heavy guns, etc., up an inclined plane or across a strip of land or in launching a ship." A cradle is built to suit conditions, and on a marine ways it is built with the top level. As the ways are on a slope the lower part of the cradle must be at the angle of the ways.

WIDTH OF SITE.

The width of site is fixed by the length of waylogs, the necessary accessories, and the storage room.

The essential accessories to the ways are power plant, hauling machinery, planing mill, carpenter shop, sheet iron shop, machine shop, blacksmith shop, pipe fitting shop, paint

shop, mold loft, store house for fittings and hardware, and general office with necessary drafting room and foremen's offices. A men's quarters with clothes lockers and tool room will be good additions. For storage of seasoned lumber, pipe, and bar iron, sheds should be built. For rough lumber a storage yard should be provided.

Zero on the river gage is 33.74 below City directrix and is assumed as the lowest stage of the river to be provided for. Before the water gets that low, the deeper draft boats will have been out of service or on the ways, while the shallow-draft boats will be too busy to lay up for repairs.

The top of the rail on the waylogs will be made to pass through zero of the river gage on the outer wharf line, and with a slope of 1 in 8 will go to elevation 40 ft. in a distance of 320 ft.

The cradle will take up about 9 ft. in height and boats without cargo will draw only 5 or 6 ft. Waylogs must then extend under water (15 X 8 =) 120 ft. from the outer wharf line; but to take care of tugs which draw 9 or 10 ft. part of the waylogs must extend (19 X 8 =) 152 ft. from the outer wharf line.

The average stage of the river is 13.7 ft. which leaves an average horizontal distance of (40 – 13.7) X 8 = 210 ft. of ways that can be used. Beyond the upper ends of the waylogs are required 20 ft. for hauling machinery, 15 ft. for railway track, 75 ft. for saw mill and shops, 15 ft. for another railway track, and 20 ft. for storage. A total of 145 ft. or with length of waylogs (320 + 145 =) 465 ft. from outer

wharf line. Of this 250 ft. is between wharf lines and may be leased from the City. The other 215 ft. or more must be acquired.

LENGTH OF SITE.

The length of site must be sufficient to include the length of the longest boat, a roadway at each end, buildings, storage room, and possible extensions.

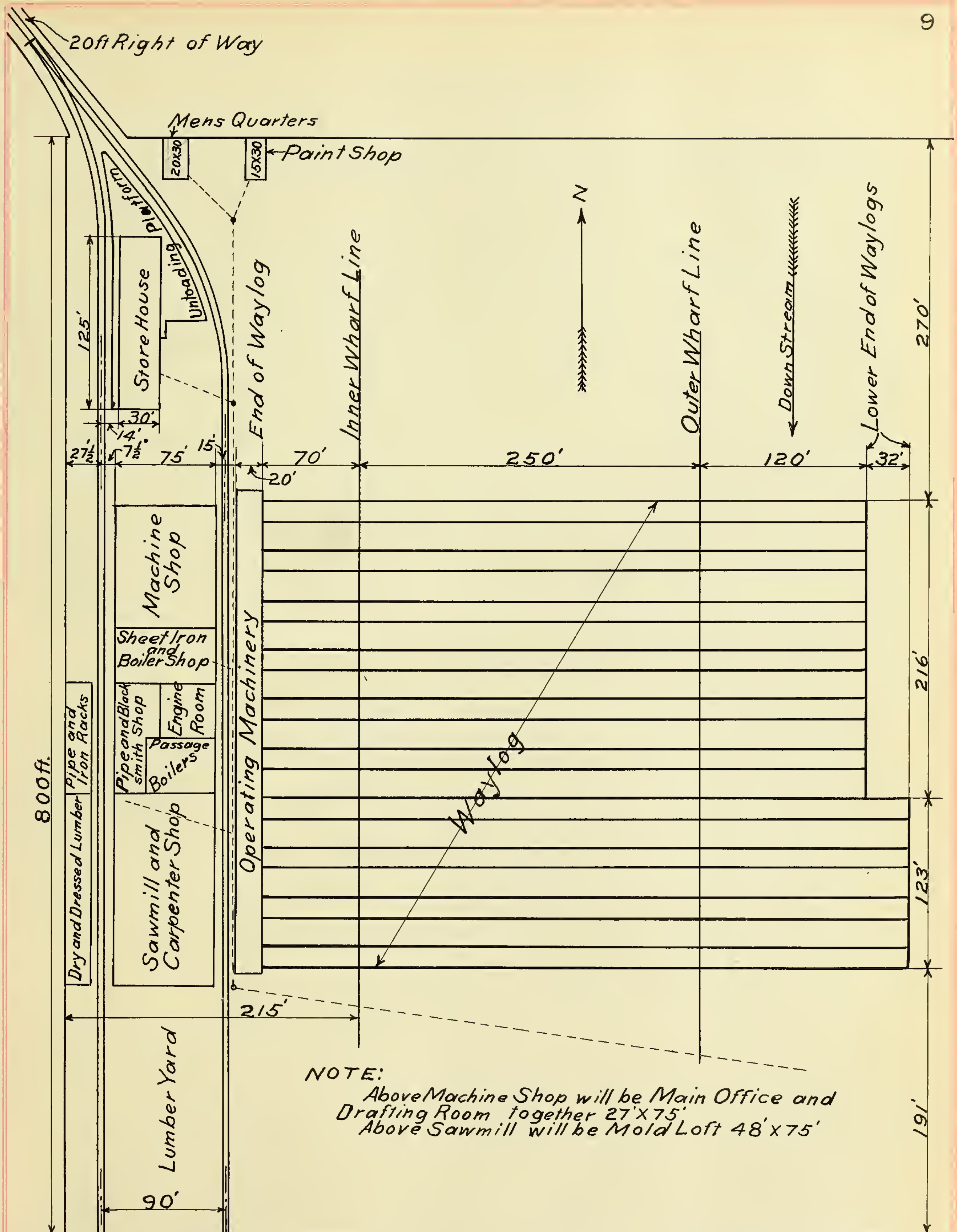
The longest boats now on the river are about 370 ft. long; while ordinary boats are 300 ft. in length. The boats may overhang the cradles at bow and stern so that from out to out of cradles a distance of about 340 ft. should be ample; but to provide for a possible longer boat, in use in a deep channel, not less than 500 ft. length should be secured for waylogs.

The store room, on account of fire, should be some distance from the nearest building. It should be about 30 ft. wide and 125 ft. long.

A building about 20 ft. by 30 ft. should be fitted for convenience of the workmen. This building should have wash room, toilet facilities, and several shower baths on the first floor, and locker room on the second floor.

With some area for storage the length should be about 800 ft. along the river. This length is exclusive of the right of way for the tracks coming from the main line.

The general lay out is better described by the following drawing, Fig. 1, page 9



GENERAL PLAN
OF
MARINE WAYS
DESIGNED BY
LOUIS METZGER
ST. LOUIS MO. 1911
SCALE 1 IN.= 100FT.

CRADLES AND WAYLOGS.

The cradles and waylogs have been defined above. The design of each is in a measure dependent on the other.

A very large cradle is cumbersome and requires the application of considerable power to move it. On the other hand a small cradle requires the use of a larger number which is also objectionable. The cradle must be amply strong to carry any load that may be put upon it. Because it is often immersed in the river and is always exposed to the weather, additional thickness of metal over and above that required for strength should be provided. Unless the cradle is kept clean and well painted its strength will soon be impaired by rust. Timber for cradles is not considered, because it must be weighted to sink; and besides, suitable timber is becoming scarce.

There is no rule or mathematical deduction for the proper spacing of the waylogs. There are so many varying conditions and so many lengths of boats that the experience of others is the only guide in spacing the waylogs. Some of the conditions that are to be considered in the spacing are: How far apart may supports be under the hull of a boat; and will the prepared surface of the ways carry the load on the supports without special preparation for each? Must part of the boat be unsupported while the cradle is backed out of the way? What are the limitations of the operating machinery and the pulling chains? After due consideration cradles are made to run on waylogs 15 ft. center to center; and there will be space between cradles with waylogs 21 ft. center to center. This allows a support every

18 ft.; and allows clearance for cradle to be backed out of the way. Distance from center of waylog to center of support is $(18 - 15) \div 2 = 1.5$ ft. This is ample for the short posts or shores used.

The widest boat now on the river has a flat bottom and is 56 ft. wide. From tentative calculations it was concluded to make the cradle 55 ft. wide in the direction of the waylogs and divide this into ten 5 ft. spaces with 2-1/2 ft. beyond center of end posts or supports.

LOAD ON CRADLES.

From a reliable builder was obtained the following list of sizes of boats with weight exclusive of superstructure, engines, boilers, and other accessories.

LENGTH.	WIDTH.	WEIGHT IN LBS.	WEIGHT PER FOOT OF LENGTH.
365 ft.	50 ft.	2,480,500	6,800 lbs.
300 "	50 "	1,681,000	5,603 "
250 "	50 "	1,320,000	5,280 "
305 "	22-1/2 ft.	2,572,000	8,433 "
196 "	56 ft.	946,000	4,827 "
206 "	56 "	850,000	4,121 "
175 "	56 "	596,000	3,406 "

The weight of a car transfer boat which the writer has calculated from the drawings and specifications is 2,095,000 lbs. The length of the boat is 305 ft., and the width, with 18 ft. 9 in. outriggers is 90 ft. The weight per ft. of

boat, exclusive of superstructure, engines, boilers, etc., is 4,175 lbs.; and the calculated weight of accessories is 822,000 lbs. Accessories, such as superstructure, engines, boilers, etc., weigh almost 40% of the total. This is considered a large boat.

The heaviest boat in the above list weighs 8,433 lbs. per foot, exclusive of superstructure, engines, boilers, etc. For the superstructure, etc., add 15% distributed over the entire length of the boat, and add 25% for engines, boilers, pumps, etc., distributed over 60 ft. of the length. The total weight per foot then is (8433 X 1.15 + 2672000 X 0.25 ÷ 60 =) 9,698 10,716 = 20,414 lbs., or say 20,400 lbs. This is an exceptionally heavy boat, for the next in weight is about 80%, and the third is about 57% as heavy.

The cradles will be designed to take the greater load and some metal will be allowed for inevitable rusting.

With waylogs spaced as stated above, ten cradles will be required extending along the river (36 X 9 + 15 =) 339 ft.

Each cradle must take care of 36 ft. of boat, and may then have a load of 20,400 X 36 = 734,400 lbs.

DESIGN OF CRADLE AND WAYLOG.

To make the cradle rigid it will be divided into panels and under each vertical will be a roller or wheel. At each side of the cradle the outside bearing will be 2-1/2 ft. from the sides. There will be eleven bearings, and ten spaces or panels of 5 ft. each. Since the side bearings will not carry a full load, assume that ten bearings on each side of

cradle each will carry a load of 734,400 X 1/10 X 1/2 = 36,720 lbs. on the assumption of equal distribution of load. To this latter must be added weight of cradle, blocking, etc., so that in round numbers, say, the total load per bearing is 38,000 lbs.

Allowable unit stress for steel shapes and rods under tension or transverse strain will be 16,000 lbs. per sq. in.; and on compression members will be 10,000 – 40 $\frac{l}{r}$.

Assuming that 38,000 lbs. is uniformly distributed on the top chord between the posts of the cradle, the bending moment is (38,000 X 60 ÷ 8 =) 285,000 in. lbs. Section modulus required is (285,000 ÷ 16,000 =) 17.81. A 9 in. 21 lb. I beam has S = 18.9; and a 10 in. 25 lb. I beam has S = 24.4, as given in "Carnegie Hand Book". On account of the wider flange and thicker metal the 10 in. 25 lb. I beam will be used for the top chord of the cradle. The chord will have a 6 in. by 10 in. timber bolted flatwise on top of the I beam. (This timber is to provide a cushion between the steel top chord and the bottoms of the boats).

Two standard railway car wheels, 24 in. in diameter, at each bearing will carry a total load of 38,000 lbs. The wheels will be forced on the axles according to the M. C. B. Specifications for car wheels and axles. Cast-iron babbitt-lined bearings will be made for the axles.

With 24 in. wheels for cradles the next to the longest post will be 74 in. from center of wheel to bottom of upper chord. The fourth post will be 59 in. from center of wheel to upper chord. Posts shorter than the last mentioned will be made

same section to limit the number of different sizes and to permit same size of rivets for all connections.

Wind load of 20 lbs. per sq. ft. normal to the direction of the wind will be assumed on boat while on the cradles. The largest boat will not have more than 10,000 sq. ft. exposed to the wind. The center of pressure will be about 13 ft. above the cradles which (with the boat on ten cradles and a width of hull of 50 ft.) will cause a wind load on each cradle of 20 X 10,000 X 13 ÷ 50 X 10 = 5200 lb., or 2600 lb. on one side. This is less than 7% of the direct load, and may be neglected, for 25% more than allowable direct load stress is permitted for wind load.

Assume the next to longest post in cradles to be made up of two 7 in. 9-3/4 lb. channels spaced six inches back to back with flanges turned in. Radius of gyration of section with axis perpendicular to center of web is 2.72; and with axis parallel to web of channel is ($\sqrt{0.98 + 2.85 \times 2.45 \div 2.85} =$) 2.52. Allowable unit stress on post is ($10,000 - 40 \frac{74}{2.52} =$) 8826 lbs. Permissible load on post is (2 X 2.85 X 8,826 =) 50,300 lb. Posts on each side of the one considered will be made of same section, two 7 in. 9-3/4 lb. channels. The low allowable unit stresses provide extra thickness of metal.

Assume two 6 in. 8 lb. channels with flanges turned in, as section of fourth longest post, and that they are six inches back to back. (The last is more than is required to make radii of gyration equal). Radius of gyration of section with axis perpendicular to web at center is 2.34. Allowable unit stress is ($10,000 - 40 \frac{59}{2.34} =$) 9,991 lb. Permissible load is (2 X 2.38

X 9,991 =) say 47,500 lb. This is more than the load, and the two 6 in. 8 lb. channels will be used for the remainder of the posts from and including the fourth.

The cross bracing necessary between posts is small, but 1/4 inch thickness of metal is the minimum; and as a 2-1/2 inch leg of an angle is the smallest that will take a 3/4 inch rivet, 2-1/2 inch leg will be the minimum size used.

The stress in the lower chord of the cradle is indeterminate. It may at times be compression, as when a lower wheel is blocked while load is on; and tension when boat is being hauled up. The lower chord will be uniform section except where flanges of channels are cut around the posts. The load on a cradle as already given is 734,400 lb.; and the weight of a cradle is estimated as 19,600 lb. Total load to be pulled then is 754,000 lb. Power required to move this load on a 1 in 8 grade is 754,000 X (0.125 + 0.992 X 0.2 =) 243,844 lb. (For this formula see P. 392 of Bowser's Analytic Mechanics). 0.125 = sine, and 0.992 = cosine of the angle of the grade; and 0.2 is the coefficient of friction of car wheels. Each lower chord, to take all the tension, should then have 7.62 square inches area. But as $\frac{125}{323}$ of power is spent in lifting the load, and $\frac{198}{323}$ in overcoming friction of resistance of wheels, and as the pull is applied to the upper chord and then transmitted to the lower chord, two six in. 13 lb. channels are estimated to be amply large for the lower chord. The channels will have webs riveted to the outside of the posts. The brace connection plates will also act as reinforcing plates on channels of lower chord at posts. Bracing between the two sides of cradle will be made as

shown on drawing. Fig. 3, page 28.

The waylogs will be built of concrete. The spacing of waylogs has been determined above. The width should be about 12 inches more than out to out of rails to avoid chipping of concrete. The length of the axle bearing in cradle will be 8 inches, which allows no clearance between rivet heads and the wheel. The middle of the tread of the wheel will be over the center of the 80 lb. A. S. C. E. rail when the rails are (8 + 5-1/2 =) 13-1/2 inches c. to c., or (13-1/2 + 2-1/2 + 2-1/2 =) 1' - 5-1/2" out to out of base.

Waylogs will be 2 ft. 6 in. wide and 3 ft. 0 in. deep. The frost line in this part of the country is about 3 ft. below the surface.

To carry the load the waylog must have better support than water soaked soil on the river bank. In the water where there is some danger of scouring, the waylog must be supported to remain in line. In the sandy soil in the river and on the bank concrete piles with 25 to 30 feet of penetration are estimated to withstand the current. Up the bank concrete piles with 15 to 20 feet penetration will carry the load. The spacing of piles is determined by considering the waylog as a beam from pile to pile and allowing nothing for strength of rail, and ignoring continuity of waylog. Allowable tensile strength of concrete in beam is 100 lbs.

Let l = distance in inches between piles and then $40{,}000\ l \div 4 = \dfrac{30 \times 36 \times 36}{6} \times 100$. l = 64.8 in. But as wheels are only 5 ft. apart, and as two loads are not wanted on same span, 60 in. or 5 ft. will be the spacing. This slightly lowers

the unit stress in the waylog. Each pile must take a load of approximately 20 tons unless the waylog is also supported by the ground. The concrete piles will project into the waylog one foot to bind them and make a rigid connection between waylog and piles. Over each pile a bearing plate 6 in. X 1/2 in. X 24 in. will be embedded in the concrete, and with a 3/4 in. by 9 in. bolt on each side of the rails and a special rail anchor will hold the rail in place. A 3/4 in. by 18 in. bolt over each pile and through the special rail anchor, the webs of rails, and the cast-iron spacing blocks, will keep the rail from traveling endwise. To keep the rails in line, the waylogs must be kept straight; and to have the cradle run smoothly on the tracks, the waylogs must be kept properly spaced. For this purpose, concrete walls 3 ft. deep and 12 in. wide, will be built between the waylogs, spaced 50 ft. c. to c. under and across the path of the cradle.

At the lower end of the way-logs must be a pocket sheave. Over this sheave a chain is operated to back the cradle down the ways. The sheave will overhang the bearing; and the shaft must be made strong enough to take the maximum strain and shock from a chain that is not always taut.

Steel wire rope was first considered. The advantages are that a wire rope or cable is not so heavy, is easier to handle, and offers less frictional resistance than chain. The disadvantages are: the elongation under load is not the same for all rope; the wear on the outer strands and the rusting throughout the whole section soon impairs the strength; by

capillary action, considerable water is held between the strands, and when in a wire rope a soft core is used this will soon mildew or rot out, and the condition of the wire rope or cable can not be known except by careful inspection.

The disadvantages of chains are that due to the non-uniform elongation under the variable load the heaviest loaded chain tends to become more heavily loaded as the cradle travels up the incline; the chains offer more resistance and are heavier than wire rope or cable; no warning is given by a chain under a load, when about to break, as in the case of a rope which yields instead of snapping suddenly. The advantages of chains are: A chain can be readily held or gripped by either a sprocket or a pocket wheel; the wear on a chain and its condition can be easily seen; the chain can be repaired if a weak place develops.

Chains were decided on as the better of two means of applying the force to move the cradle.

The resistance offered in moving the cradle is made up of two parts which are due to gravity and to friction. When the cradle is going down the incline gravity assists in moving the load so that the power required is the difference between gravity and frictional resistance. This is (0.2 X 0.992 – 0.125) X 754,000 = 55,350 lb. To this must be added the resistance offered by the weight of the chains and the friction of and in them. For lowering the cradle and the load (55,350 ÷ 4 =) 13,838 lb. of force are required on each of four chains. The force required to move the chain must be added to this to

determine the strength of the shaft for pocket wheel at the lower end of the waylog.

For the approximate weight of chain a manufacturer's catalog was consulted. Here is listed a 7/8 in. dredge chain weighing 8 lb. per ft., and having a working strength of approximately 17,300 lb. The weight of one strand of back-up chain will be about 3800 lb. The pulling chains shall be specially designed, but for the present purpose the manufacturer's catalog weight will answer. A chain which might fulfill the requirements will weigh about 18,000 lb. per strand. For the combined strands the approximate weight of the chain will be about 22,000 lb. Since not all of the chain will drag and offer resistance, and as the coefficient of friction is a very doubtful factor, it will be safe to assume that 6,000 lb. will be required to move the chain when the cradle is going up and about one third as much, or 2,000 lb. when the cradle is going down.

For lowering the cradle about 16,000 lb. pull is required on each chain, so that the shaft carrying a pocket wheel on each end must resist a force of 32,000 lb. on each end or a total load of 64,000 lb. on the shaft. Due to the shock caused by the swaying of the chain, an additional load of 25% of that calculated will be provided for in the shaft on which are the pocket wheels at the lower end of the waylogs. The total load to be taken is 80,000 lb.

The pocket wheel will be 26 in. diameter, with its center outside of the cradle wheel flanges. This size of wheel

leaves 4 in. between the top of the waylog and the pitch line of the wheel when the center of the pocket wheel shaft is in the same plane as the center lines of the cradle wheel axles. The shaft will be made to remain stationary. Allowing 4,000 lb. per sq. in. for bearing of cast iron on wrought iron shaft, there are required 20 sq. in. of area. The shaft will be made 5-1/2 in. diameter to resist the bending movement, and will be clamped tightly in a rigid cast iron pillow block which will bear against the concrete of the waylog extended up for that purpose. A 1-1/2 in. thick disc held on the end of the shaft by a 1-3/4 in. stud bolt, will keep the pocket wheel on the shaft; and a collar will keep the wheel against the disc. An allowable pressure of 500 lb. per square inch on concrete will require for area of the base of the pillow block (80000 ÷ 500 =) 160 sq. in. The base of the pillow block will be much larger.

From the center of the lower chord to the outside of the wheel is 9-1/2 in. Allowing 3 in. more for clearance of the chain, the center of the chain will be 12-1/2 in. from the center of the waylog. The chain will be hitched to the cradle by an extra heavy clevis and a 1-3/4 in. diameter connecting pin. Between wheels 1 and 2 a plate and an angle will be riveted to the top and to the bottom of the lower chord of the cradle to receive the connecting pin. Six rivets are required for each side of the lower chord to hold each 14 in. by 7/16 in. plate; and to stiffen the plate, and also to take the pin, a 5 in. by 3-1/2 in. by 3/8 in. angle will be riveted to it.

The load on each pulling chain is (with the load of chain resistance) 243,850 ÷ 4 + 6,000 = 66,960, which requires

5.36 sq. in. of steel in tension with an allowable unit stress of 12,500 lb. per sq. in. Allowing 12,000 lb. per sq. in. of bearing area of steel on steel, then 11.16, or say 11.2 sq. in. are required. In the 0.31 in. thickness of web in the 10 in. by 25 lb. I beam of the top chord forty seven 3/4 in. rivets are required. Since not that number of rivets can be put in the web, some of the rivets will be put into the flanges of the I. beam. With the center of the chains 12-1/2 in. from the center between the rails the bending moment for the connecting bar will be (12-1/2 X 66,960 =) 837,000 so that the section modulus required is (837,000 ÷ 12,500 =) 67. A rectangular section having this section modulus is 11-5/8 in. by 3 in. The bending moment on the pin in this bar will be (3.75 X 66,960 =) 250,100 in. lb. which requires a pin 5-1/4 in. diameter. In order not to make the bar much larger, a driving fit will be made for the pin in the connecting bar on the compression side; and the bar will be made 12 in. wide, so that the center line can be made tangent to the pin. The end of the bar will be made to receive a rod 3 in. in diameter. This rod will be threaded for two and one-half feet and be supplied with a standard nut at the lower end; and it will be properly connected to the pulling chain at the other end.

The bar and rods will be used to equalize the stress in the two chains at each waylog, and also to take up some of the slack in the chains in warm weather.

Detail of waylog given in Fig. 2, page 27.

OUTLINE OF OPERATING MACHINERY.

As stated above each chain may be stressed 66,960 lb. and then the total load on the engine, exclusive of friction in the transmission gear will be 66,990 X 4 X 10 = 2,678,400. It is desired to move the cradles, when fully loaded, 3 ft. per minute so that (2,678,400 X 3 ÷ 33,000 =) 243 H. P. are required. Since the friction in the transmission gear will absorb upward of 35% of the power applied to the gear, an engine of 400 H. P. will be installed. This will be a two cylinder, high-speed, high-pressure, non-condensing engine, with ordinary slide valve and reversible link. The cranks will be set at right angles to each other so that the engine can be started from any position with a load and also so that the torque in the main shaft will be more uniform than with a single cylinder.

The engine will be placed in the middle 21 ft. space, with five cradles on each side. The line shaft must transmit (400 ÷ 10 =) 40 H. P. to each cradle or 20 H. P. at each waylog. This power will be transmitted through gears to the shaft on which is the pocket wheel to move the pulling chains that are attached to the cradles. Worm gears were first considered to reduce the speed of the shafting, so that the speed of the cradles will be 3 ft. per minute. Since worm gears absorb more power than plain cog wheels, or plain gears, the latter will be used. As it has been shown above that power must be applied to move the cradles down the incline, there is no

danger that the gears will be run by the weight of the cradles. The speed reducing gear will be carried on shafts with bearings on concrete walls which are in line with the waylogs. The gears will be in the 15 ft. spaces with the one shaft overhanging to carry the pocket wheels. Provision, by means of square jawed clutches, will be made to operate any one or any number of the cradles.

The engine will be housed in a brick building, with 9 in. walls and a flat roof covered with a prepared roofing of burlap and asphalt. On the side toward the shops will be a door 4 ft. wide by 7 ft. high, and also a window. On the river side will be two windows. For the hauling chains openings will be left of suitable size. All openings for shafts and chains will be so made that, while the machinery is not in use, they can be closed to keep out the cold and bad weather.

The gear and shaft will be sheltered by a steel-frame shed covered with corrugated asbestos siding and roof. This shed will be the full length of the ways and have 5 ft. openings on each side in the 21 ft. spaces between the cradles, except at the ends where closets are to be installed. These two sections will have a smooth concrete floor.

MAIN BUILDING.

The main building will be located as shown on the general plan of the marine ways. The lower floor will be occupied by a saw-mill, a carpenter shop, a boiler room, an engine room, a pipe and blacksmith shop, a boiler and sheet iron shop,

and a machine shop. Main offices and drafting room will be on the second floor above the machine shop, and the mold loft and pattern shop will be on the second floor above the saw-mill and carpenter shop. The building will be built with 13 in. brick walls, will have ample window area, and will have a composition gravel roof. The plan and elevations, Fig. 4, page 29, show the general character and dimensions of the building.

The arrangement of, and the number of machines will be left to a mechanical engineer.

PAINT SHOP.

The paint shop will be used for storing painters' supplies and for an oil house. Space on the first floor will be reserved for the mixing of paints and storage of pigments, and a small quantity of oils. Ample window area will be provided to avoid as much as possible the use of artificial light. Only stationary electric lights will be used. The second floor will be lighted by sky-lights, and will have a ventilator to carry off all oil vapors. This building is shown in Fig. 5, page 30.

STORES BUILDING.

The stores building will be one story with platforms around it at the height of a car floor, and will be located between the tracks, as shown in Fig. 1, page 9. The windows in this building will be cut down to a minimum on account of the two sky-lights. The foundation will be put 4-1/2 ft. below the surface of the ground, so that a cellar may be made under this

building which is shown in Fig. 6, page 31.

MEN'S QUARTERS.

The men's quarters will be two story, as shown in Fig. 7, page 32. On the lower floor will be five shower baths, four bath tubs, twelve lavatories, two urinals, and as many 16 in. by 14 in. by 6 ft. lockers as can be placed along the walls or back to back in space not otherwise occupied or necessary for passages. On the second floor will be a rest room, provided with tables and chairs, and for convenience a closet and two urinals will be installed. A stairway outside of the building will lead to the second floor.

SEWERAGE & CLOSETS.

Sewers will be run from the buildings to the main sewer, lying between the shelter for the operating machinery and the railway track, and from the lower end of the shelter will turn down grade to terminate at the low water line. The water from the roofs of the building will be conducted to the sewer, so that the sewers will be flushed at times of heavy rains. The sewer from the men's quarters and from the paint shop, will join and continue in a 6 in. vitrified clay pipe until it is joined by the sewer from the store room, from where it will continue in an 8 in. vitrified clay pipe until it is joined by the sewer from the machine shop, and from where it will continue in a 10 in. vitrified clay pipe to the outfall.

There will be no toilet facilities in the paint shop, but a sink with water supply will be installed. The closets, etc., in the men's quarters have been mentioned above. In the store room one closet and a sink will be installed. On the second floor of the main building, above the machine shop, for the office and drafting room force, one closet, one urinal, and one lavatory will be provided. On the second floor, at the other end of the main building, no toilet fixture will be placed, but a large cast iron sink will be provided. For the machine shop and boiler shop, four closets, one urinal trough about eight feet long and a cast iron sink will be provided. For the saw mill and pipe shop three closets, one urinal trough about six feet long, and a cast iron sink will be provided. In the end 21 ft. spaces under the gear shelter will be vaults with 2 in. by 6 in. rail for the seat; and a hose connection will be provided for washing the floor, and the vault. Manholes will be built at the junction of sewers from the paint shop and the men's quarters, and at or near each end of the gear shelter. Sewers are shown by dotted line in Fig 1, page 9.

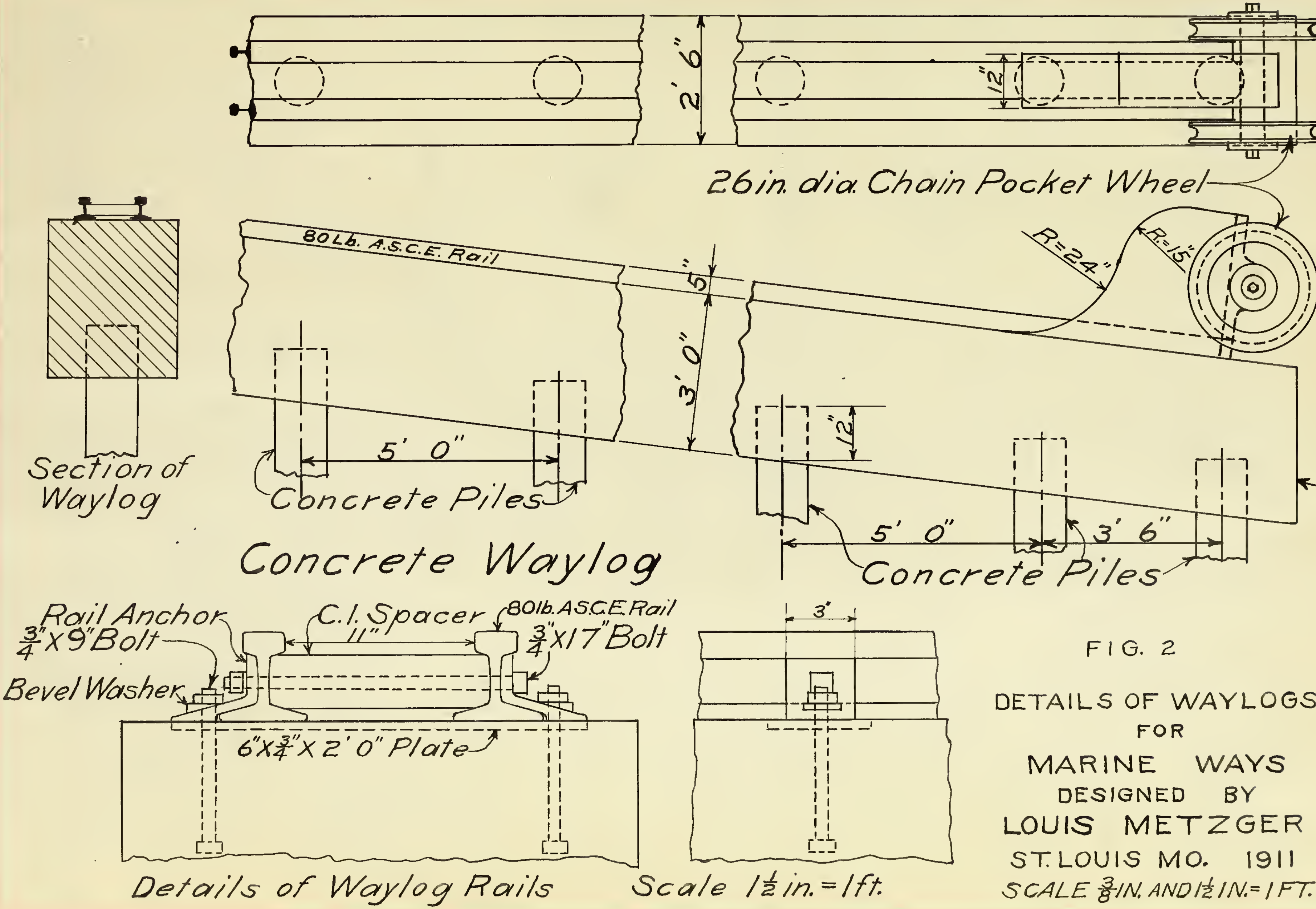


FIG. 2

DETAILS OF WAYLOGS
FOR
MARINE WAYS
DESIGNED BY
LOUIS METZGER
ST. LOUIS MO. 1911
SCALE 3/8 IN. AND 1 1/2 IN. = 1 FT.

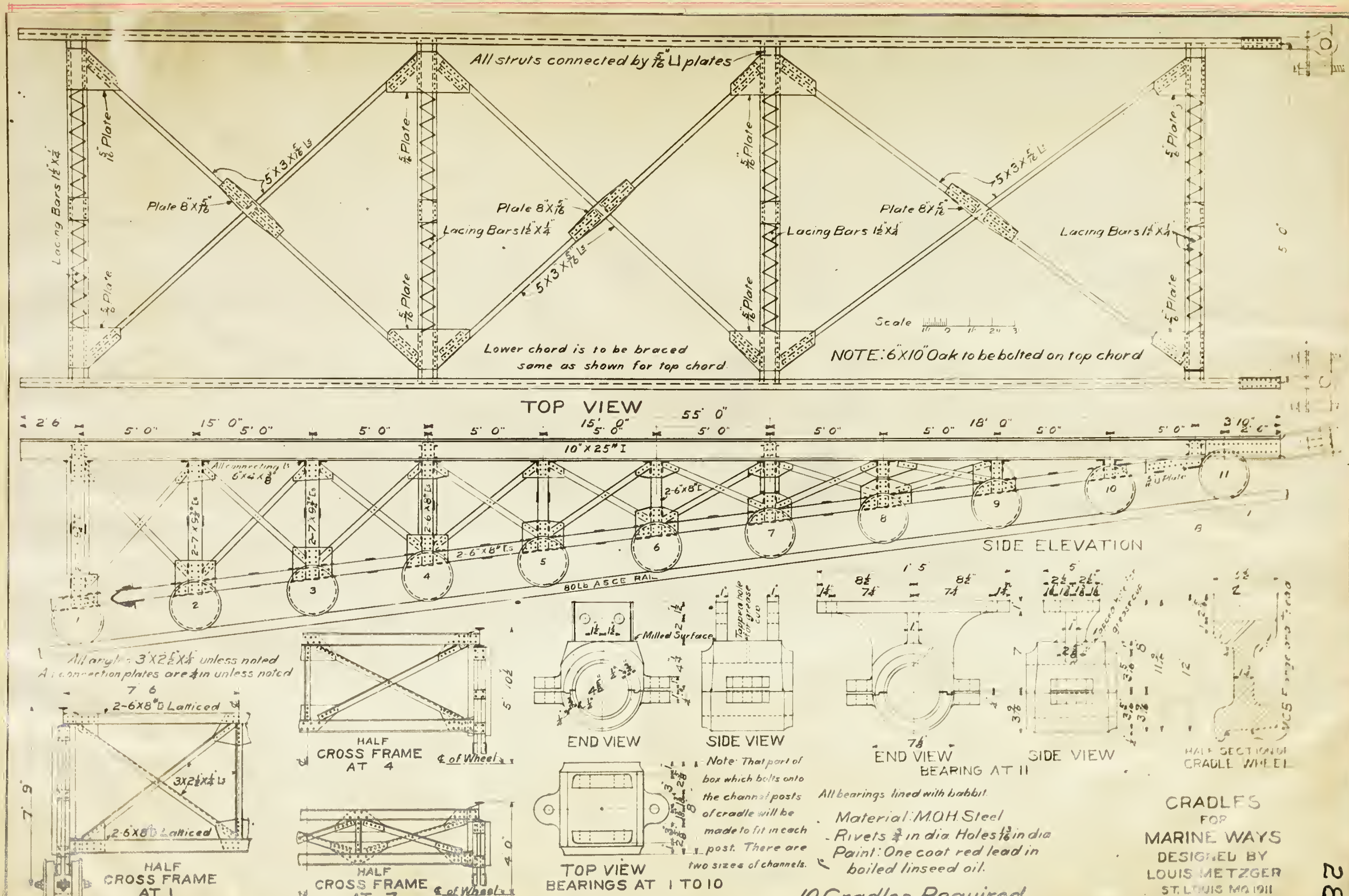
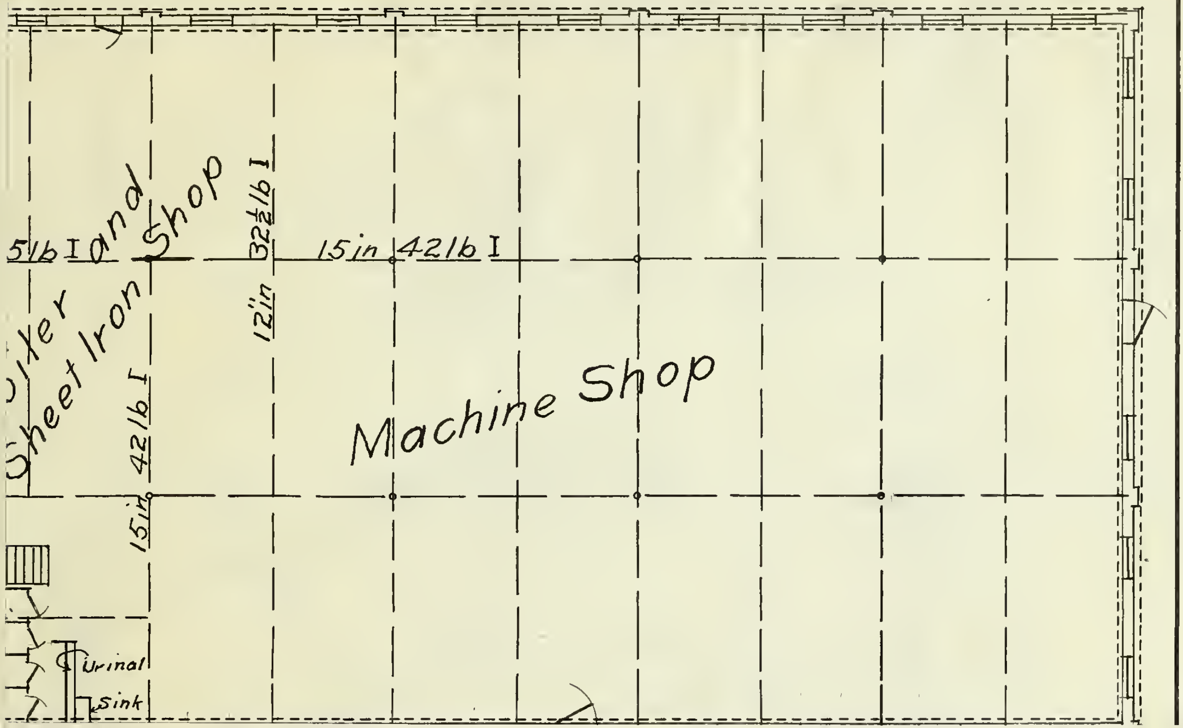

All struts connected by 5/16" ⊔ plates
Lacing Bars 1½"X¼"
5/16" Plate
Plate 8"X5/16"
5X3X5/16" Ls
Lower chord is to be braced same as shown for top chord.
NOTE: 6"X10" Oak to be bolted on top chord
Scale
TOP VIEW
55' 0"
10"X25# I
All connecting Ls 6"X4"X3/8"
2-7X9¾" Ls
2-6"X8" Ls
80Lb ASCE RAIL
SIDE ELEVATION
All angles 3"X2½"X¼" unless noted
All connection plates are ¼in unless noted
2-6X8" ⊔ Latticed
3X2½X¼ Ls
HALF CROSS FRAME AT 1
HALF CROSS FRAME AT 4
HALF CROSS FRAME AT 7
℄ of Wheels
Milled Surface
Tapped hole for grease cup
END VIEW
SIDE VIEW
TOP VIEW
BEARINGS AT 1 TO 10
Note: That part of box which bolts onto the channel posts of cradle will be made to fit in each post. There are two sizes of channels.
END VIEW
SIDE VIEW
BEARING AT 11
HALF SECTION OF CRADLE WHEEL
All bearings lined with babbit.
Material: M.O.H. Steel
Rivets ¾ in dia. Holes 13/16 in dia
Paint: One coat red lead in boiled linseed oil.
10 Cradles Required
CRADLES FOR MARINE WAYS
DESIGNED BY LOUIS METZGER
ST. LOUIS MO. 1911

FIG. 3.



Machine Shop
Sheet Iron Shop
15 in 42 lb I
12 in 32½ lb I
42 lb I
15 in
Urinal
Sink

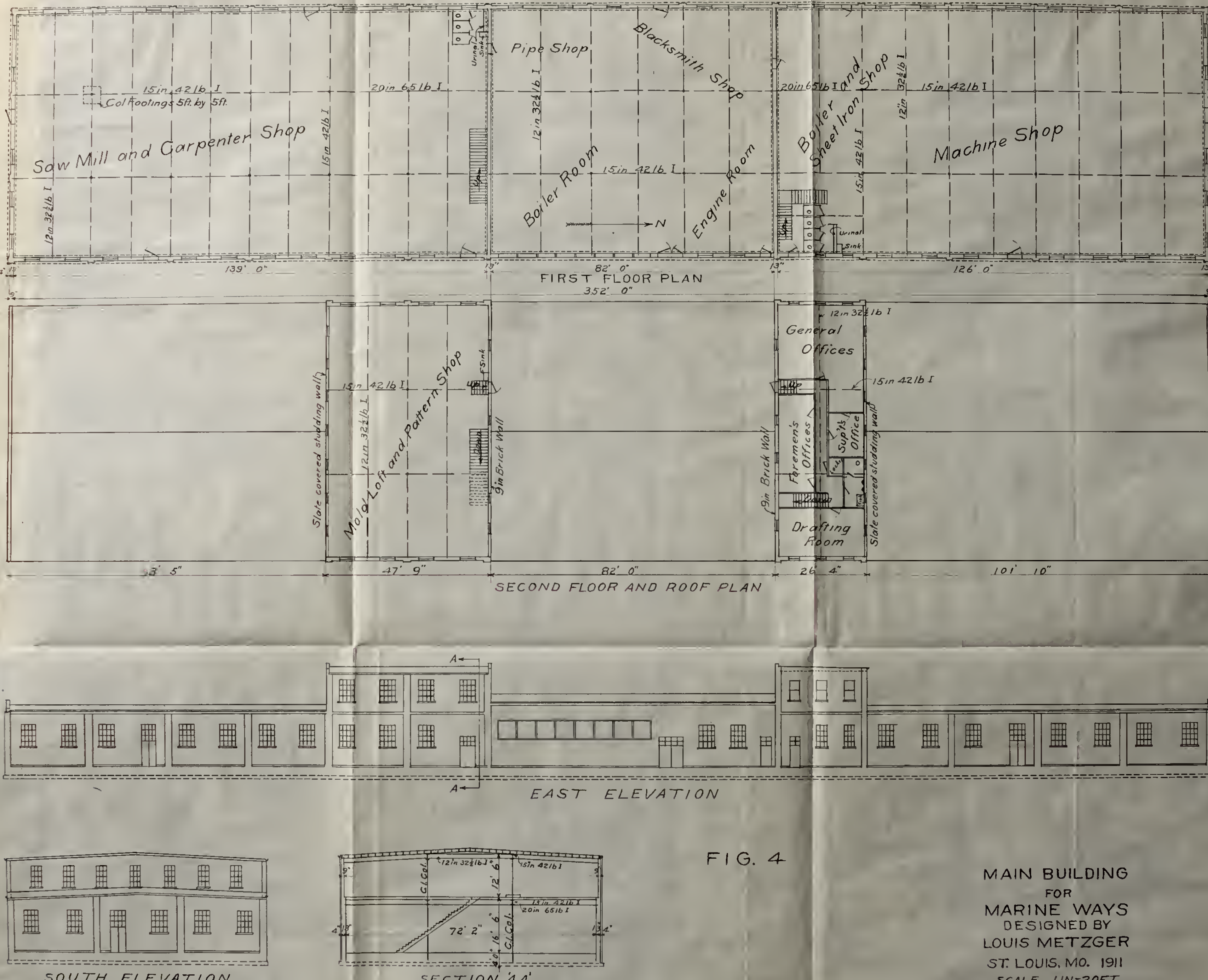


FIG. 4

MAIN BUILDING
FOR
MARINE WAYS
DESIGNED BY
LOUIS METZGER
ST. LOUIS, MO. 1911
SCALE 1 IN.=20FT.

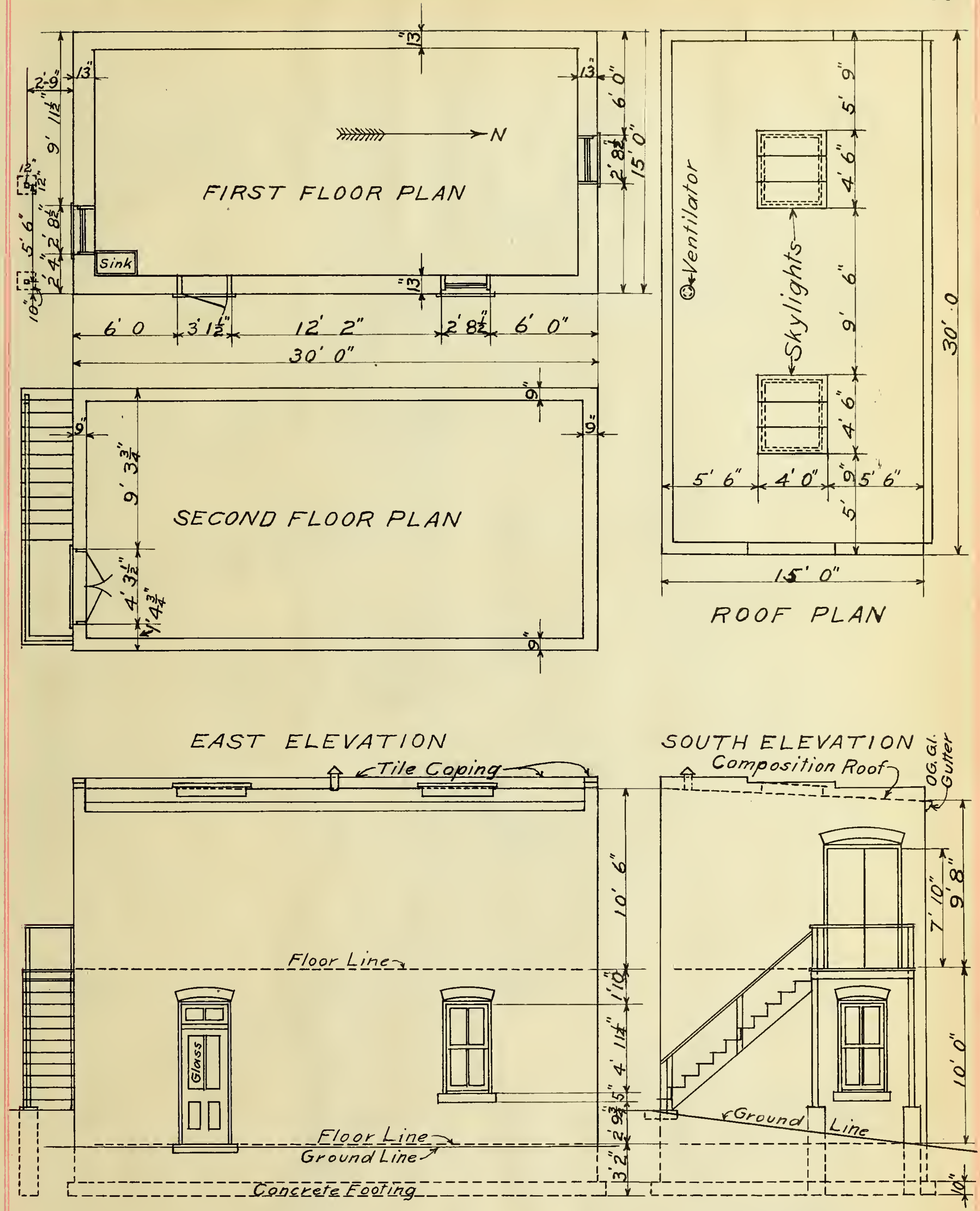


FIG. 5

PAINT SHOP
FOR
MARINE WAYS
DESIGNED BY
LOUIS METZGER
ST. LOUIS MO. 1911
SCALE $\frac{1}{8}$ IN.=1 FT.

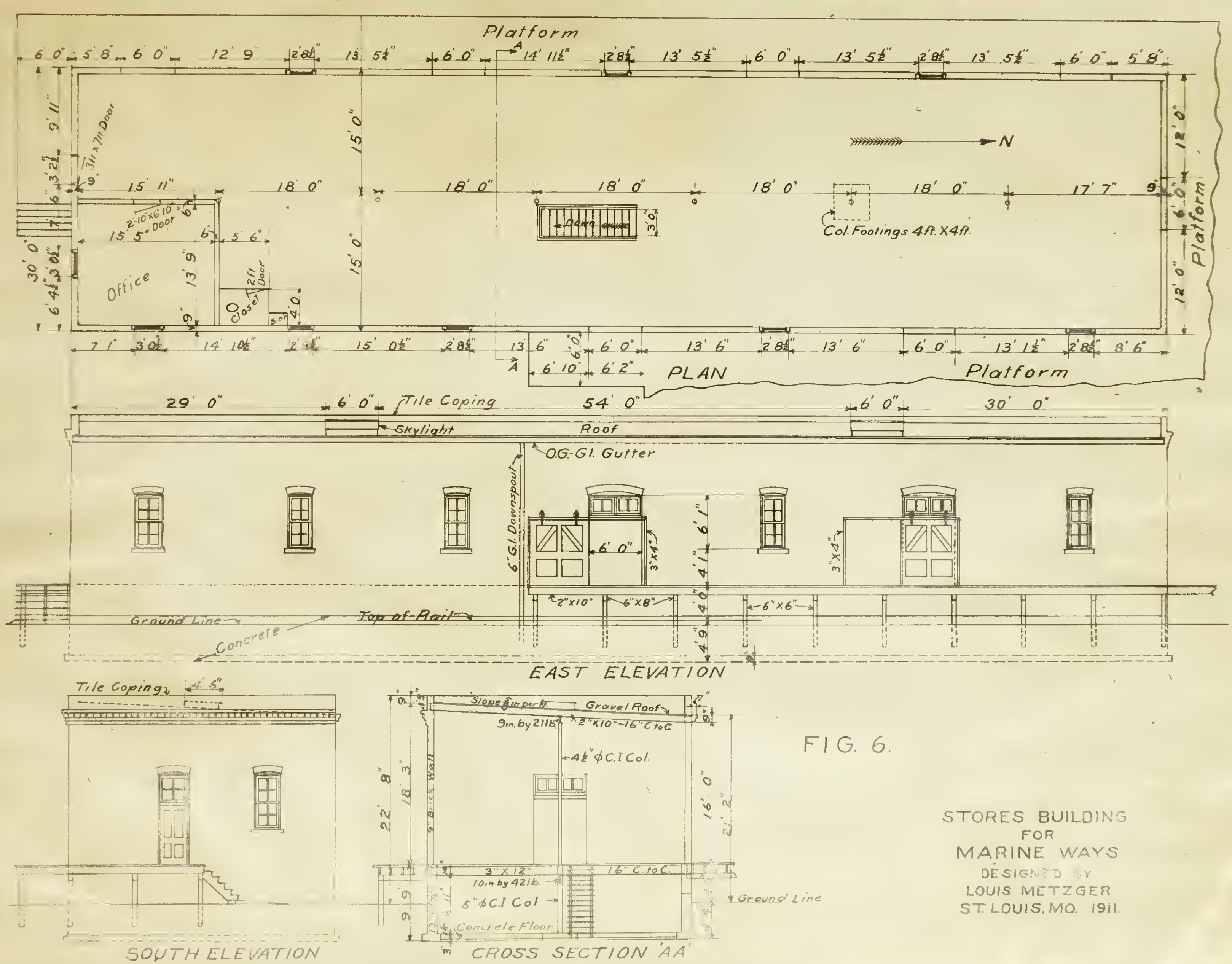


FIG. 6.

STORES BUILDING
FOR
MARINE WAYS
DESIGNED BY
LOUIS METZGER
ST. LOUIS, MO. 1911.

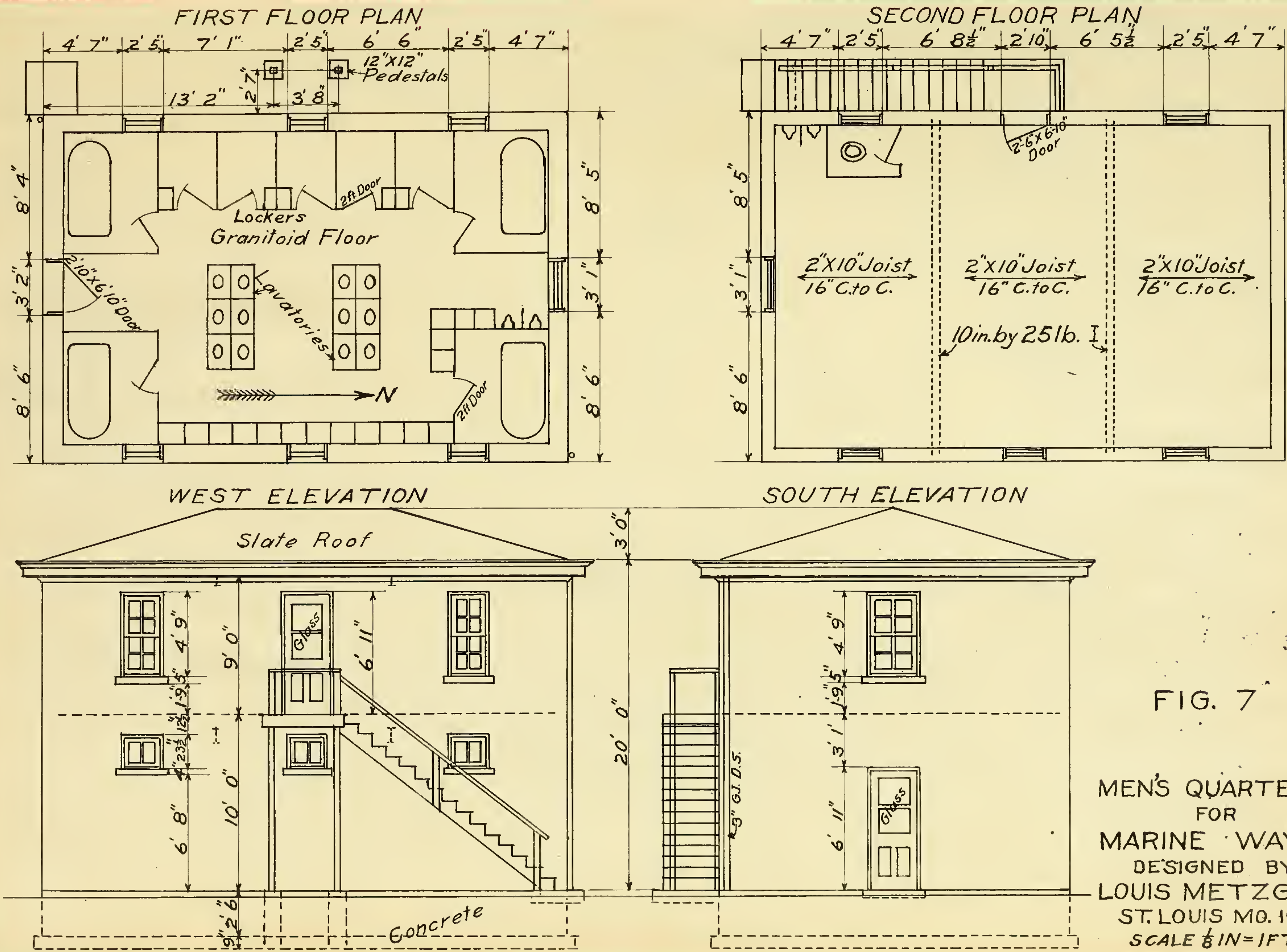


FIG. 7

MEN'S QUARTERS
FOR
MARINE WAYS
DESIGNED BY
LOUIS METZGER
ST. LOUIS MO. 1911
SCALE 1/8 IN = 1 FT.